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# Effect of Lag and Dwell Time on Balanced Mix Design Testing

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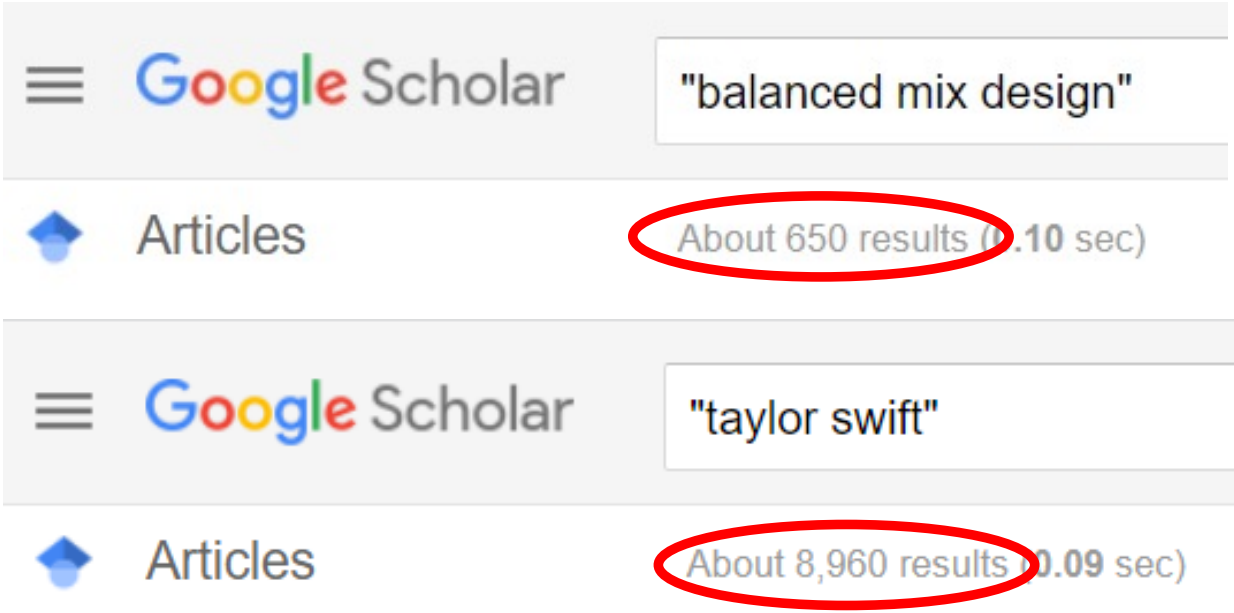
# Are you getting a little tired hearing about these topics?

**Balanced Mix Design**

**Taylor Swift & Travis Kelce**

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# Does this look familiar?

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# What are you getting out of this?

Work so far on impact of **Dwell** and **Lag** time for BMD testing

Impact is trending to be not significant so far

Stay tuned…

- **Lag time** = Duration between asphalt mixture sampling and sample compaction.
- **Dwell time** = Duration between asphalt mixture compaction and mechanical testing.

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# Background

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# Balanced Mixture Design (BMD)

- FHWA collaborates with stakeholders to advance and implement BMD in an impartial and data-informed manner
- Per AASHTO PP 105-20, BMD is defined as:
  - "asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate, and location within the pavement structure."

**What are the key points of that definition?**

- Use of performance tests
- Appropriately conditioned specimens
- Multiple modes of distress (more than rutting and cracking)
- Taking into account the use of the mixture

Design "philosophy" used to optimize the mix performance against distresses pertinent to the climate & traffic specific to the region where it will be placed.

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# Motivations

- Potential stiffening effect of aging of samples.
- Impacts largely unconfirmed yet cited for source of variability.
- BMD usage (especially in quality assurance) will likely require reheating.

"If we can't reheat mixtures, then we might as well not investigate BMD any further"

-Anonymous DOT

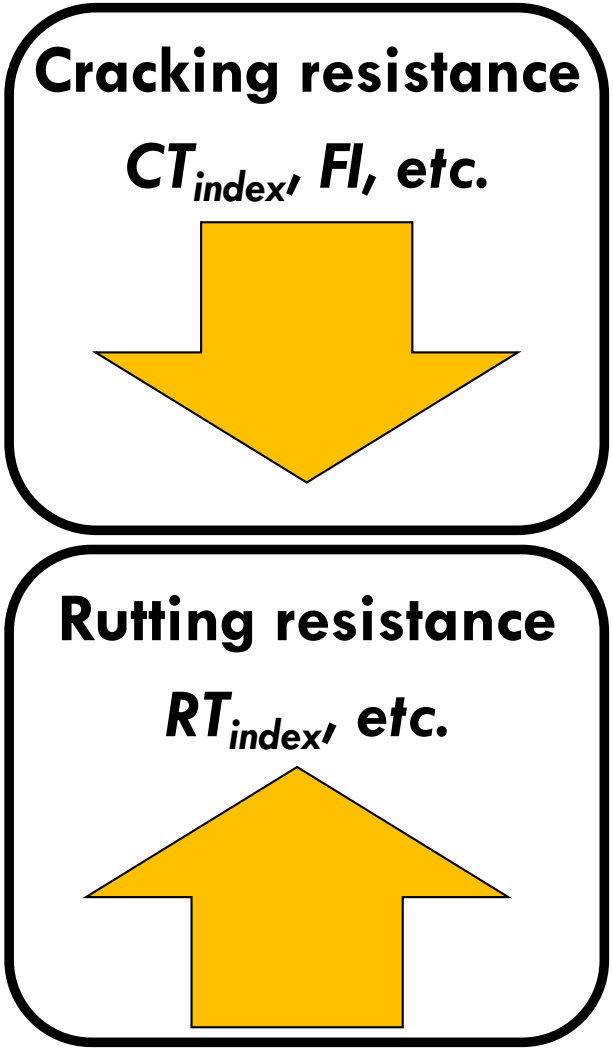
# Hypothesis & Objective

**#1** Reheating the mixture will significantly affect the BMD results due to aging and added conditioning.

**#2** Increased lag time between sampling and compaction will affect the BMD results due to added aging.

**#3** Increased dwell time between compaction and testing will affect the BMD results due to added aging.

Compare $CT_{index}$, $RT_{index}$, and Volumetric Properties with the impact of reheating and dwell time.

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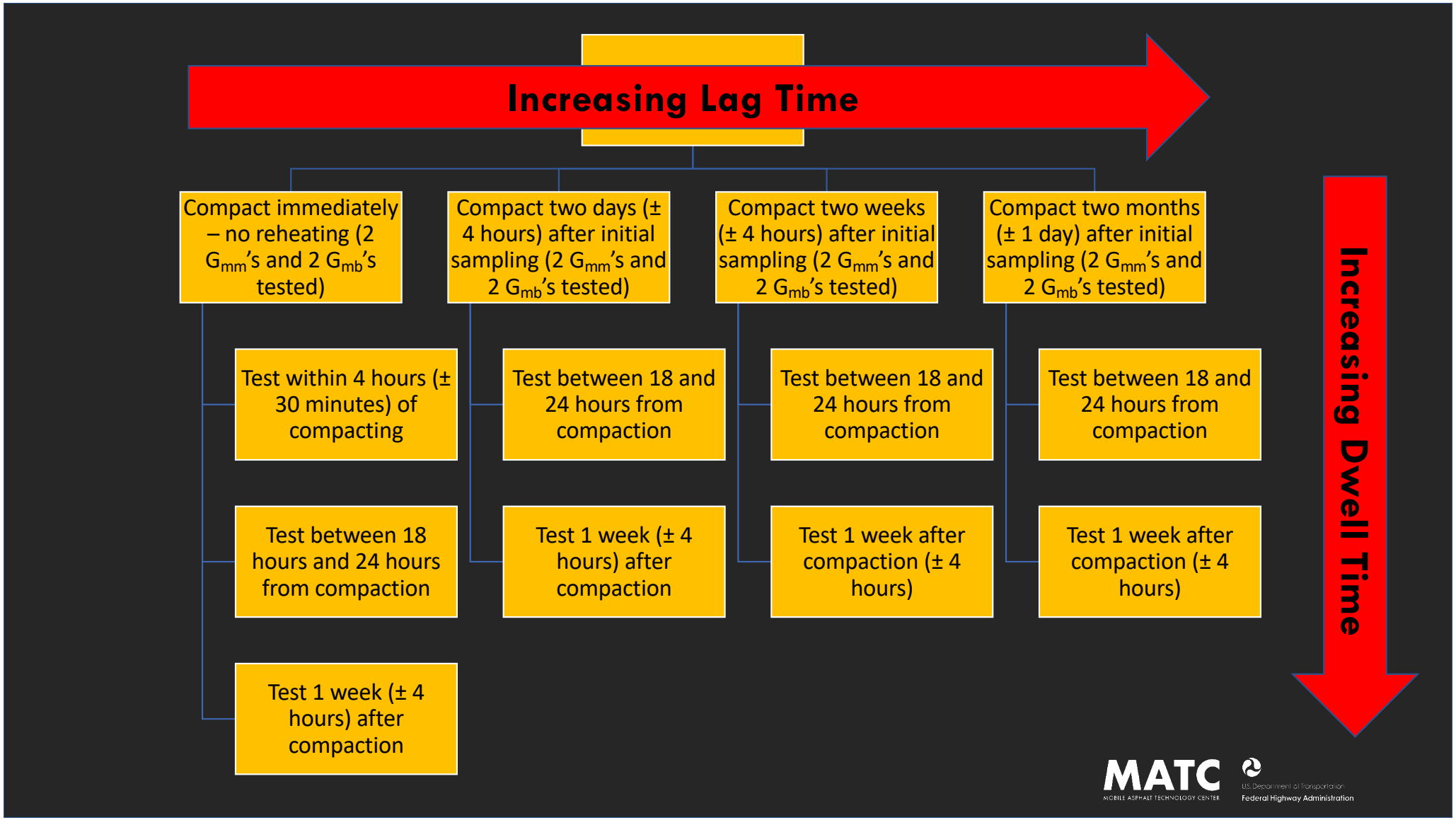
Increasing Lag Time
Compact immediately – no reheating (2 $G_{mm}$'s and 2 $G_{mb}$'s tested)
Compact two days (± 4 hours) after initial sampling (2 $G_{mm}$'s and 2 $G_{mb}$'s tested)
Compact two weeks (± 4 hours) after initial sampling (2 $G_{mm}$'s and 2 $G_{mb}$'s tested)
Compact two months (± 1 day) after initial sampling (2 $G_{mm}$'s and 2 $G_{mb}$'s tested)
Test within 4 hours (± 30 minutes) of compacting
Test between 18 and 24 hours from compaction
Test between 18 and 24 hours from compaction
Test between 18 and 24 hours from compaction
Test between 18 hours and 24 hours from compaction
Test 1 week (± 4 hours) after compaction
Test 1 week after compaction (± 4 hours)
Test 1 week after compaction (± 4 hours)
Test 1 week (± 4 hours) after compaction
Increasing Dwell Time
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# Methodology Notes

- Testing performed = IDEAL-CT & IDEAL-RT for each box with a minimum of five replicates each, Two $G_{mb}$'s @$N_{des}$ for volumetrics determination.
- An average of two $G_{mm}$'s will be used for void determination for each of the compaction conditions.
- All samples stored in the same place in boxes or buckets
- All replicates for a given testing condition to be compacted consecutively.
- All replicates for a given testing condition to be tested consecutively as close to each other as possible.

# Methodology Notes

- Each mix bucket quartered per AASHTO R47, batched, and reheated at (300F) at regular intervals for no more than two and a half hours and then compacted.

- The samples bulked, core dried, and conditioned in our environmental chamber per the test method before testing.

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# Mixtures

- Three mixtures completed with testing plan to date:
  - 9.5 mm NMAS PG64-22 – Virginia
    - $CT_{index}$ target ~ 100
  - 9.5 mm NMAS PG67-22 – Alabama
    - $CT_{index}$ target ~ 30
  - 9.5 mm NMAS PG76-22 – Alabama
    - $CT_{index}$ target ~ 70

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# VA Results

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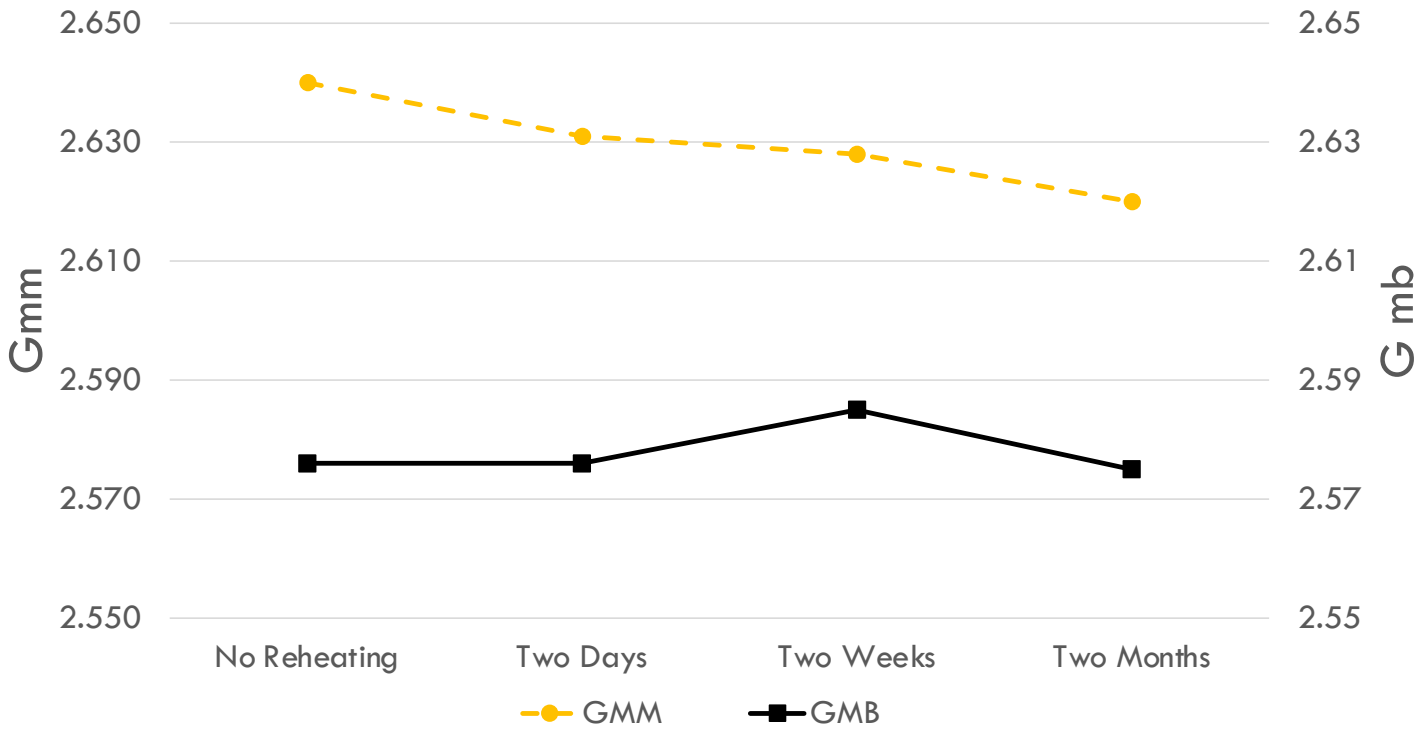
# Specific Gravity Results




VA Mixture

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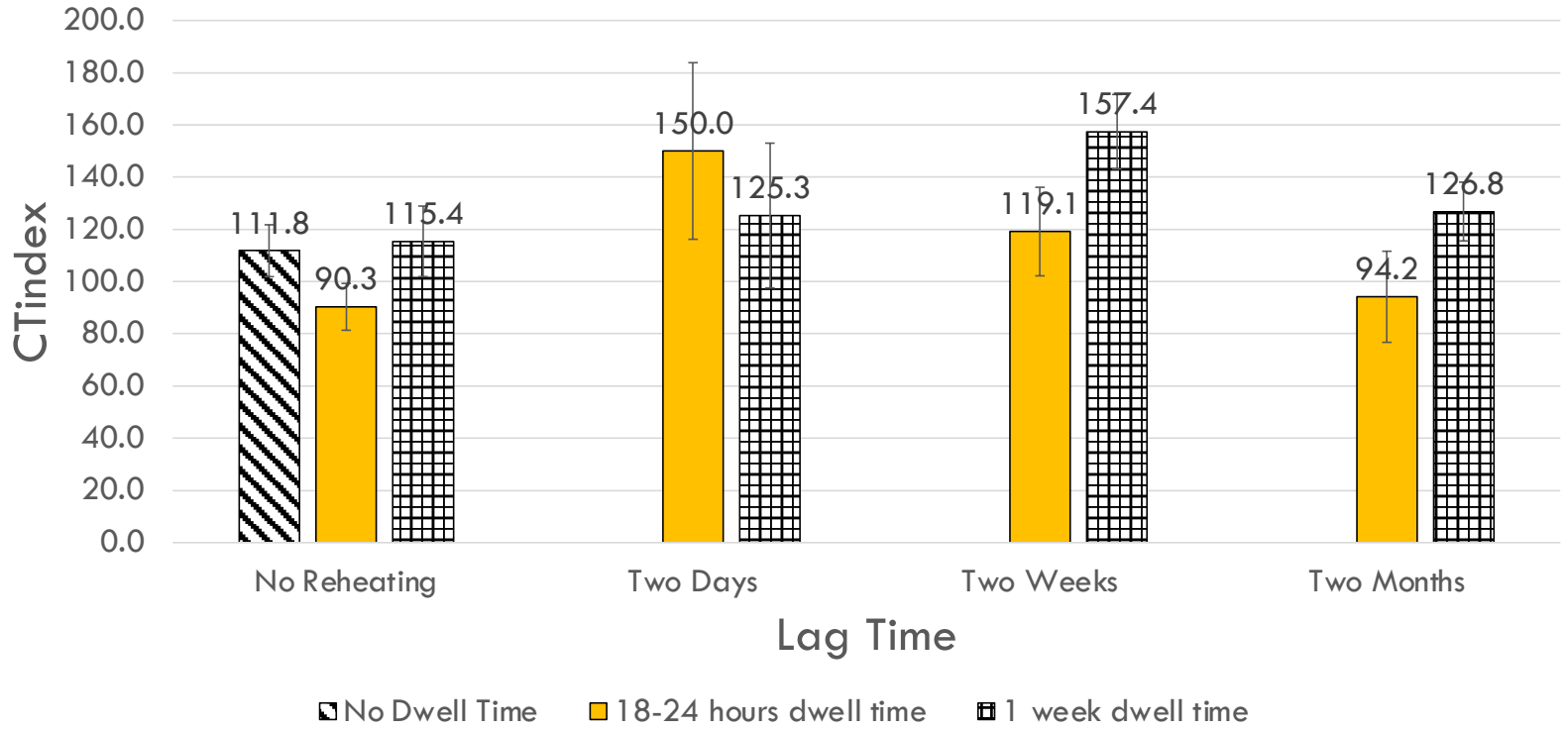
# $CT_{index}$ Results

| Lag Time | No Dwell Time | | | 18-24 hours Dwell | | | One Week Dwell | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg. CT Index | SD | COV (%) | Avg. CT Index | SD | COV (%) | Avg. CT Index | SD | COV (%) |
| No Reheating | 111.8 | 9.9 | 8.9 | 90.3 | 9.0 | 9.9 | 115.4 | 13.5 | 11.7 |
| Two Days | N/A | | | 150.0 | 33.8 | 22.5 | 125.3 | 27.7 | 22.1 |
| Two Weeks | N/A | | | 119.1 | 17.0 | 14.2 | 157.4 | 14.3 | 9.1 |
| Two Months | N/A | | | 94.2 | 17.4 | 18.5 | 126.8 | 11.3 | 8.9 |

VA Mixture

# $CT_{index}$ Results




Note: Error bars signify one standard deviation

VA Mixture

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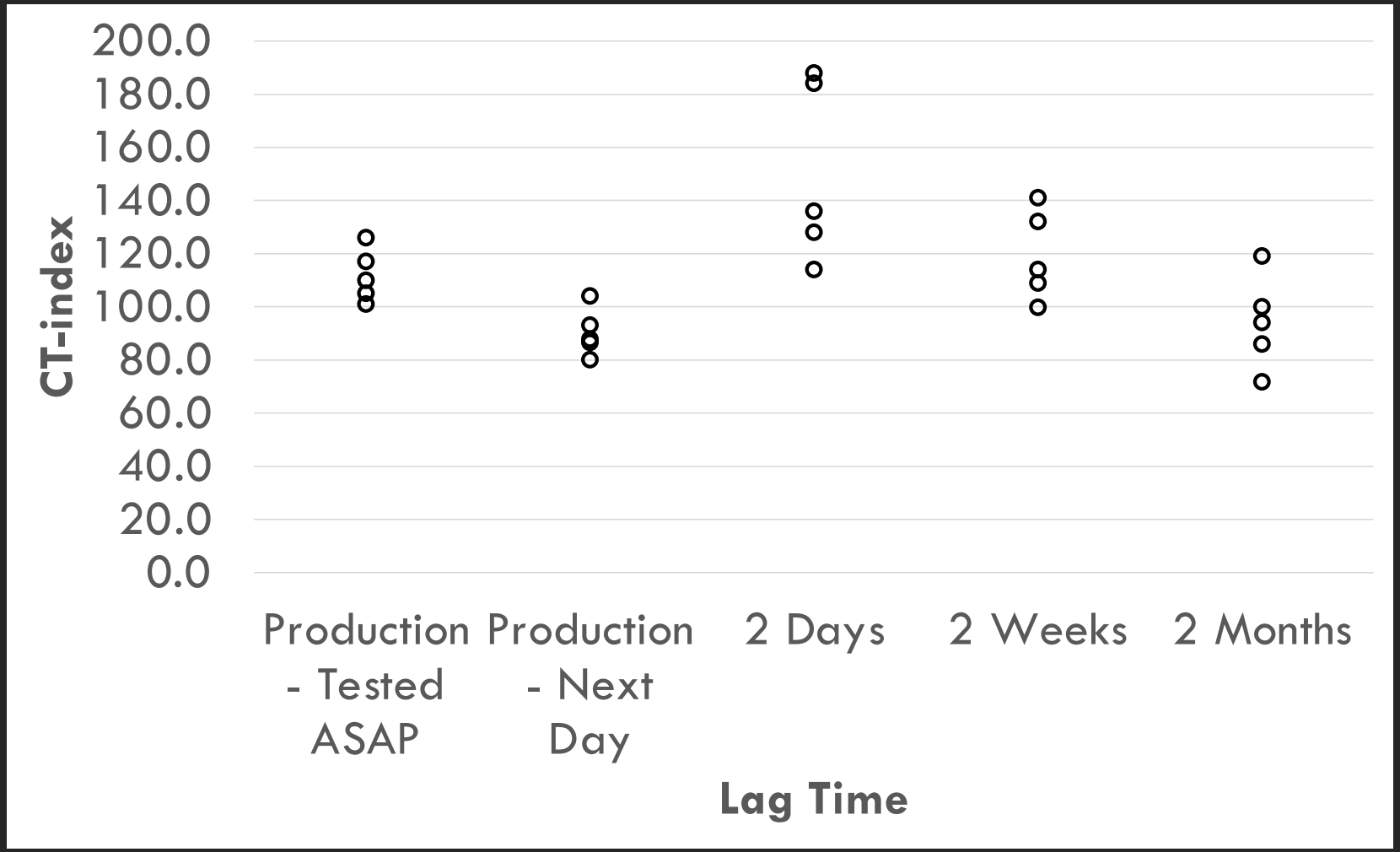
# $CT_{index}$ 18-24 Hours Dwell

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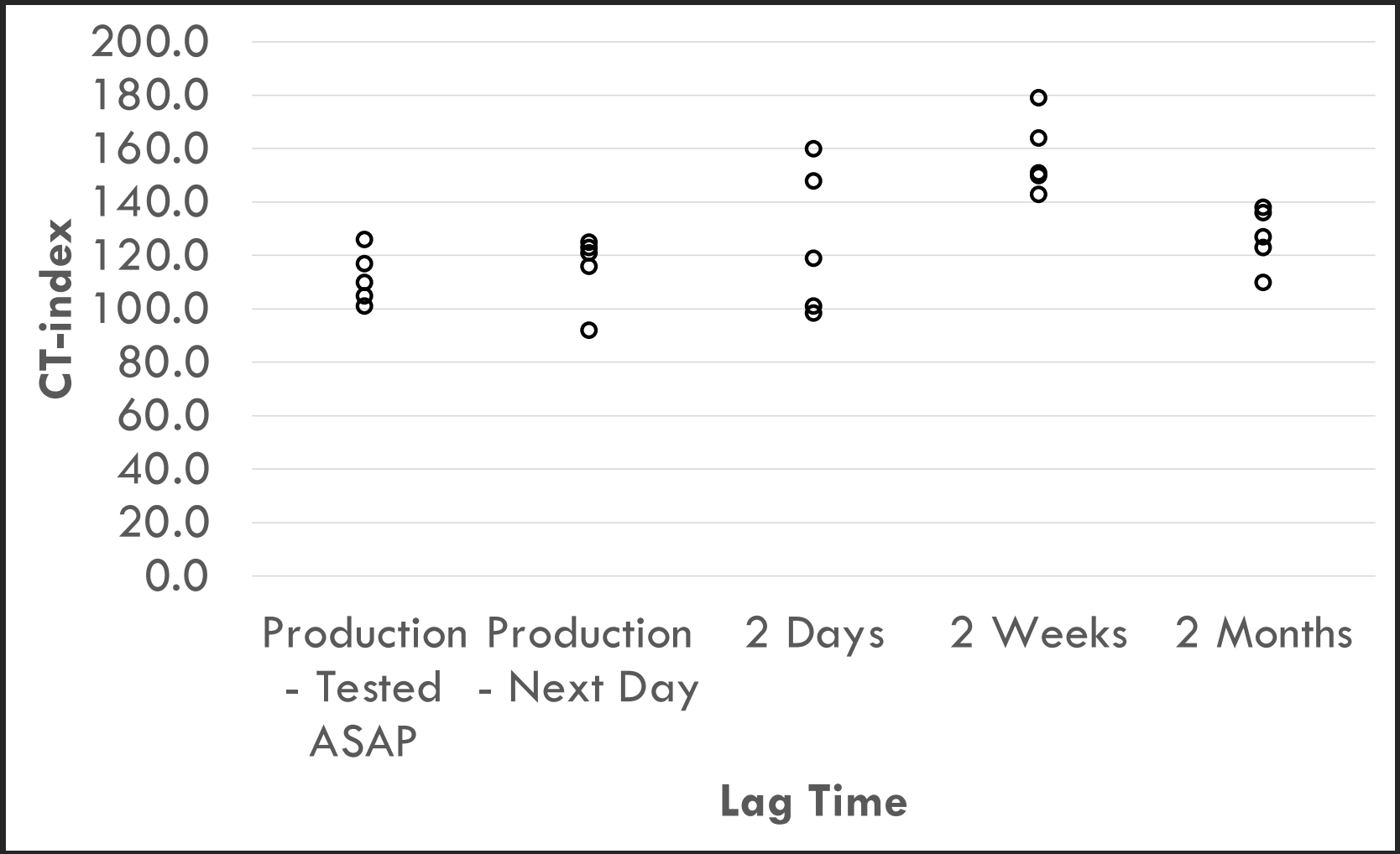
# $CT_{index}$ 1 Week Dwell




VA Mixture

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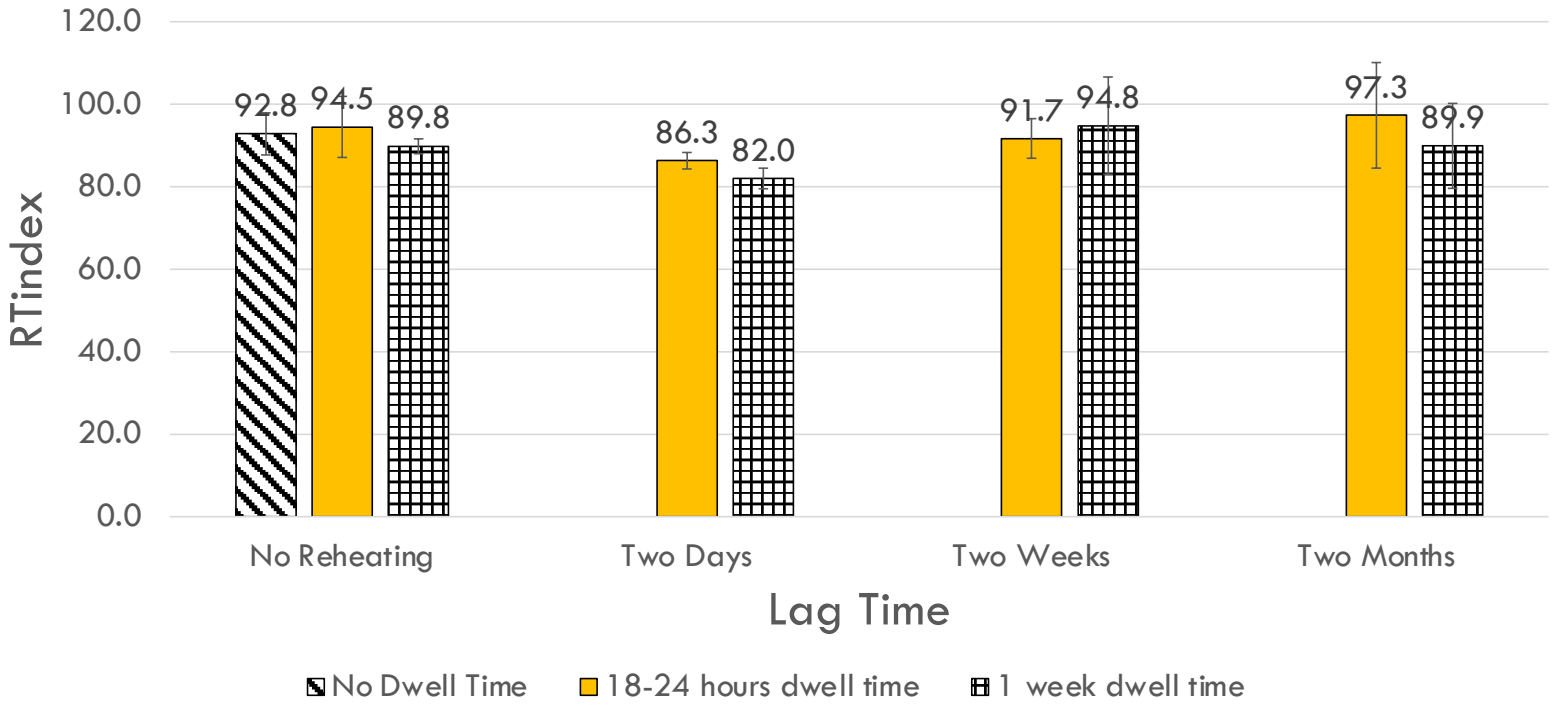
# $RT_{index}$ Results

| Lag Time | No Dwell Time | | | 18-24 hours Dwell | | | One Week Dwell | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg. RT Index | SD | COV (%) | Avg. RT Index | SD | COV (%) | Avg. RT Index | SD | COV (%) |
| No Reheating | 92.8 | 5.1 | 5.5 | 94.5 | 7.4 | 7.8 | 89.8 | 1.8 | 2.0 |
| Two Days | N/A | | | 86.3 | 2.0 | 2.3 | 82.0 | 2.5 | 3.1 |
| Two Weeks | N/A | | | 91.7 | 4.8 | 5.2 | 94.8 | 11.8 | 12.5 |
| Two Months | N/A | | | 97.3 | 12.8 | 13.2 | 89.9 | 10.3 | 11.5 |

# $RT_{index}$ Results




Note: Error bars signify one standard deviation

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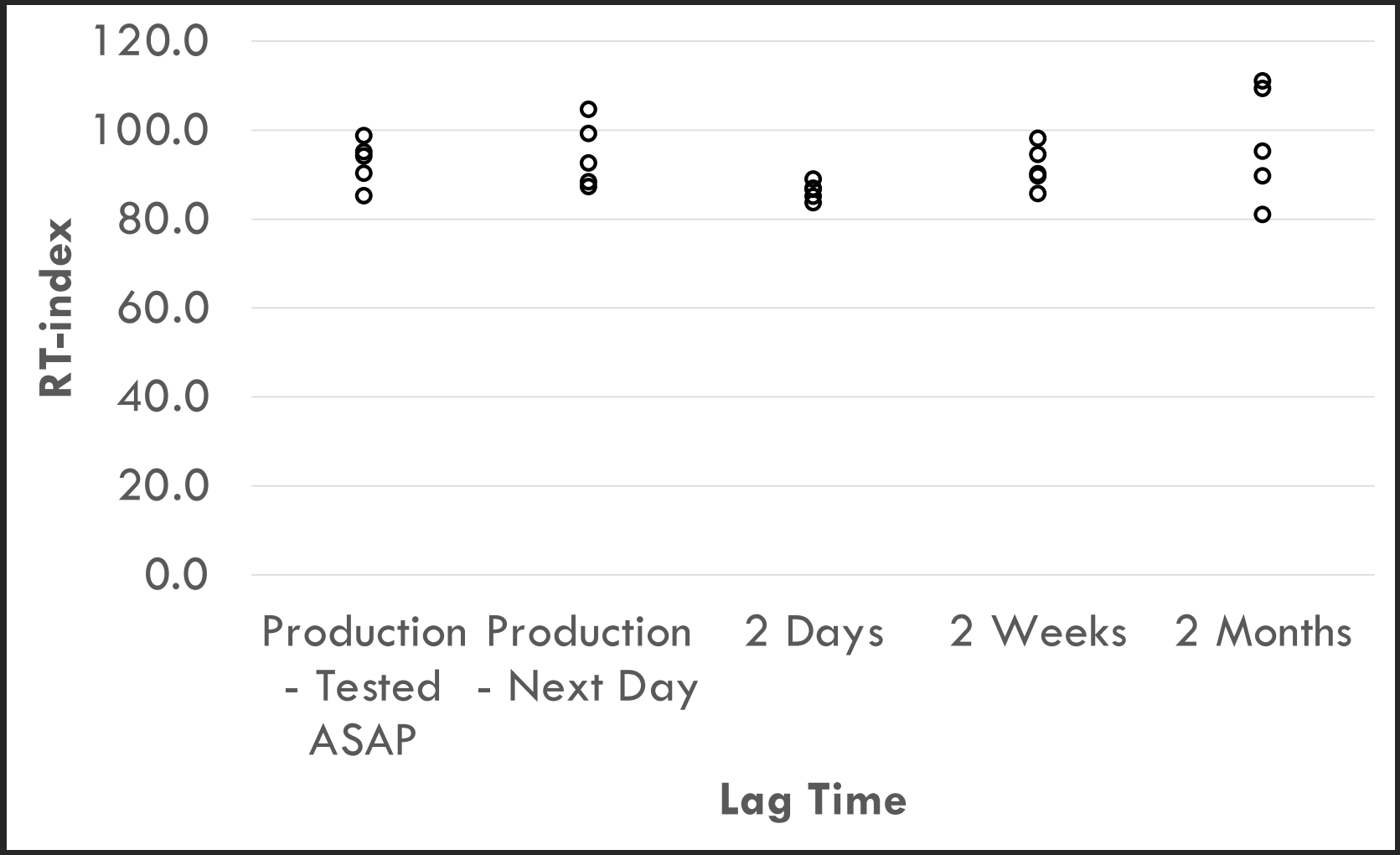
# $RT_{index}$ 18-24 Hours Dwell




AL Mixture #1

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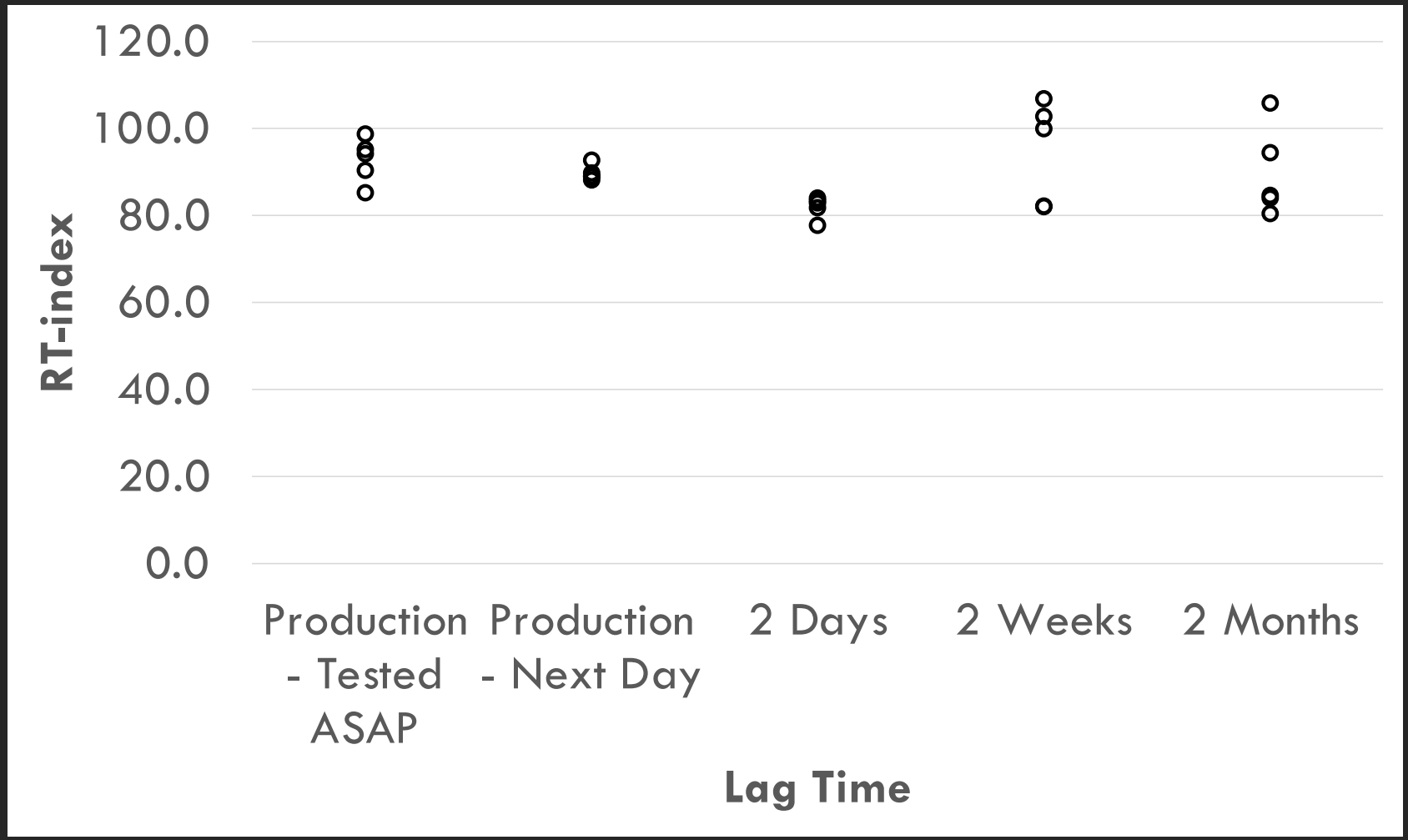
# $RT_{index}$ 1 Week Dwell

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# VA Summary

- $CT_{index}$ from 90.3 to 157.4
  - No clear trend for dwell or lag time
- $RT_{index}$ from 82.0 to 97.3
  - No clear trend for dwell or lag time
- No clear trend on variability

AL Mixture #2

# NCAT #1 Results

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# $CT_{index}$ Results

| Lag Time | No Dwell Time | | | 18-24 hours Dwell | | | One Week Dwell | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg. CT Index | SD | COV (%) | Avg. CT Index | SD | COV (%) | Avg. CT Index | SD | COV (%) |
| No Reheating | 29.9 | 4.0 | 13.6% | 29.0 | 4.3 | 14.8% | 32.0 | 3.5 | 11.0% |
| Two Days | N/A | | | 25.6 | 2.9 | 11.4% | 25.5 | 4.1 | 16.0% |
| Two Weeks | N/A | | | 29.5 | 4.4 | 14.8% | 29.2 | 5.1 | 17.6% |
| Two Months | N/A | | | 24.7 | 2.2 | 8.9% | 25.2 | 2.0 | 7.8% |

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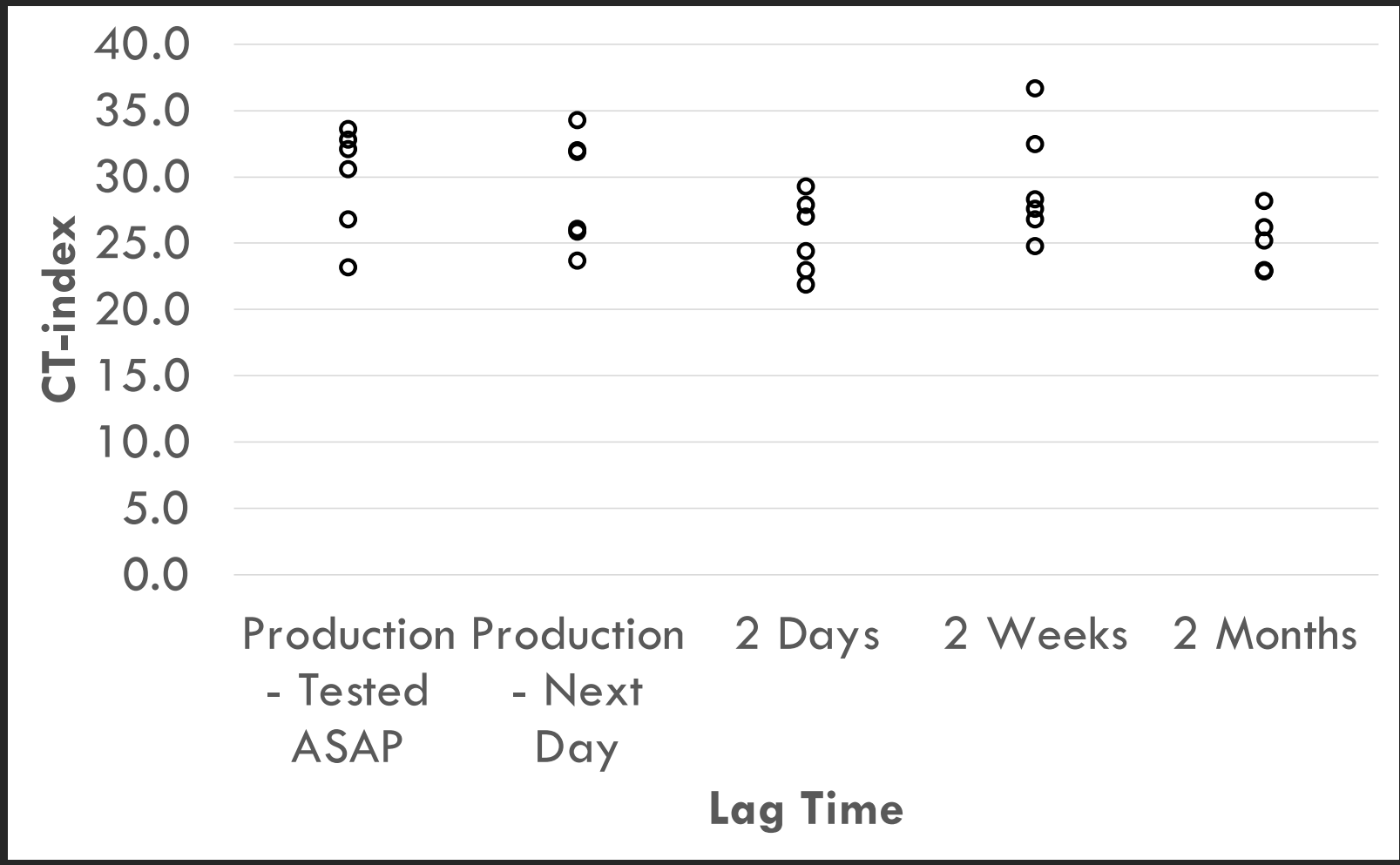
# $CT_{index}$ 18-24 Hours Dwell

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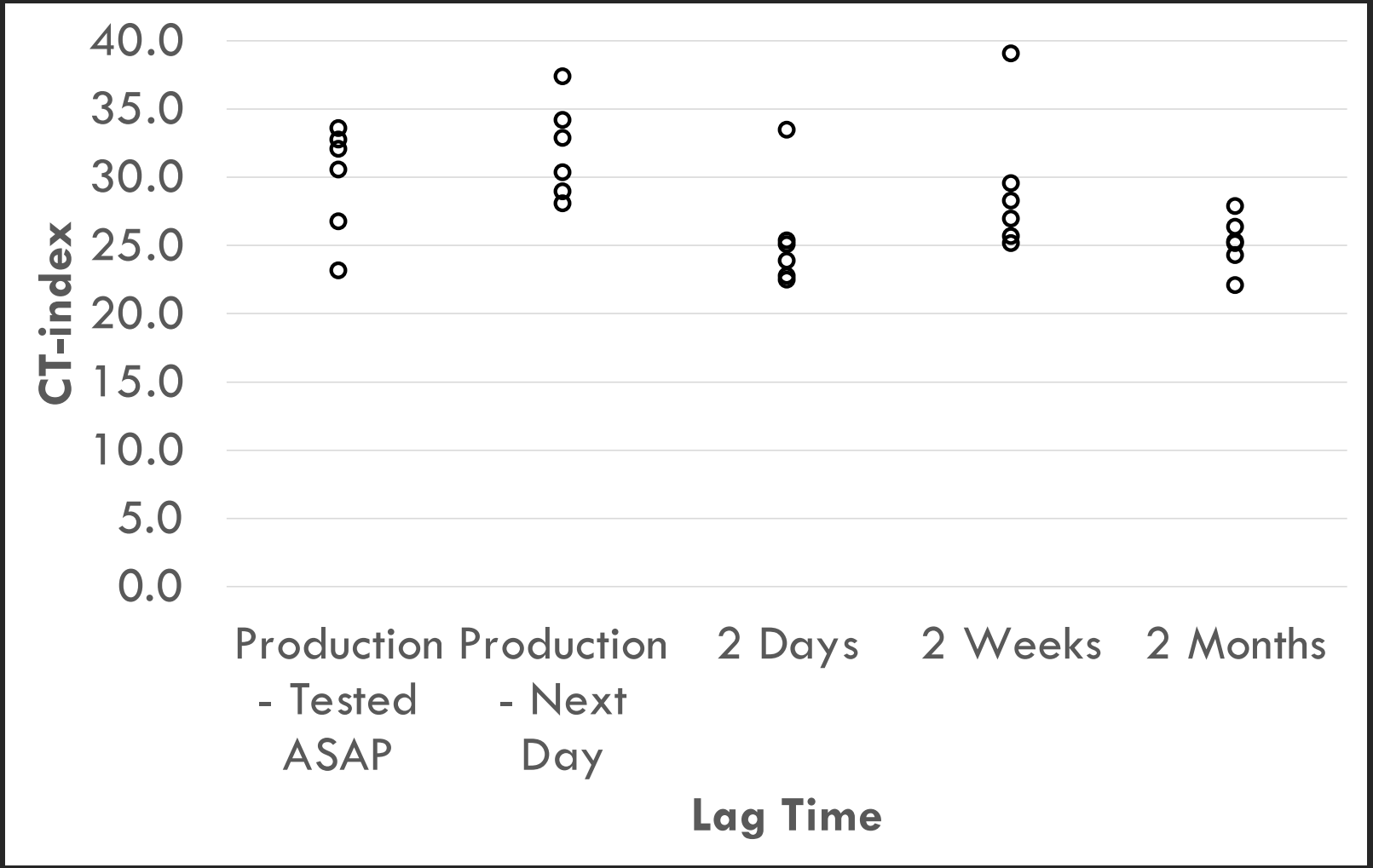
# $CT_{index}$ 1 Week Dwell

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# $RT_{index}$ Results

| Lag Time | No Dwell Time | | | 18-24 hours Dwell | | | One Week Dwell | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg. RT Index | SD | COV (%) | Avg. RT Index | SD | COV (%) | Avg. RT Index | SD | COV (%) |
| No Reheating | 109.9 | 7.1 | 6.5% | 111.4 | 8.7 | 7.8% | 101.7 | 4.8 | 4.7% |
| Two Days | N/A | | | 114.7 | 2.9 | 2.5% | 121.2 | 3.6 | 3.0% |
| Two Weeks | N/A | | | 114.6 | 3.1 | 2.7% | 98.5 | 7.5 | 7.6% |
| Two Months | N/A | | | 107.8 | 2.3 | 2.1% | 109.5 | 2.7 | 2.4% |

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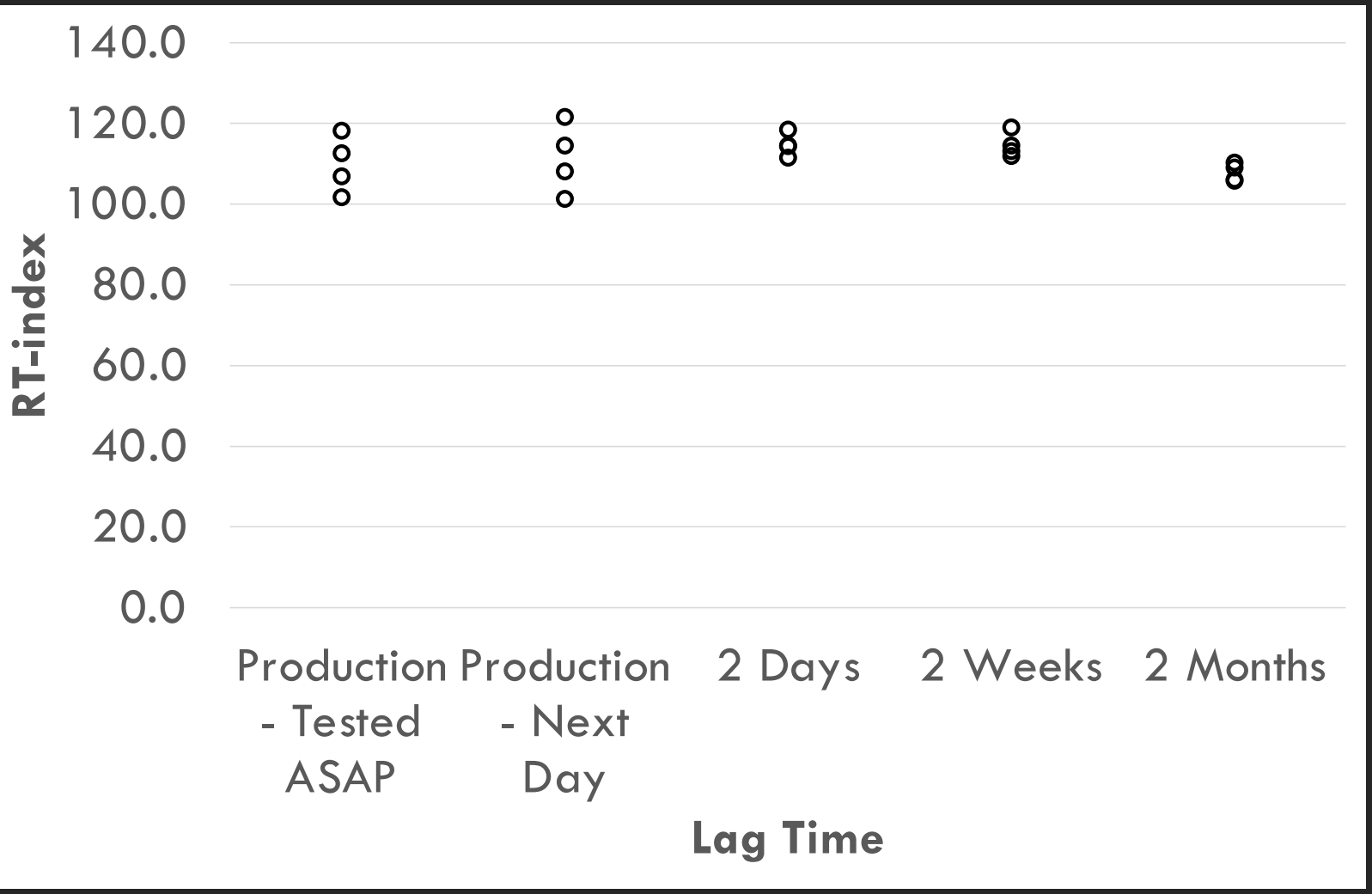
# $RT_{index}$ 18-24 Hours Dwell

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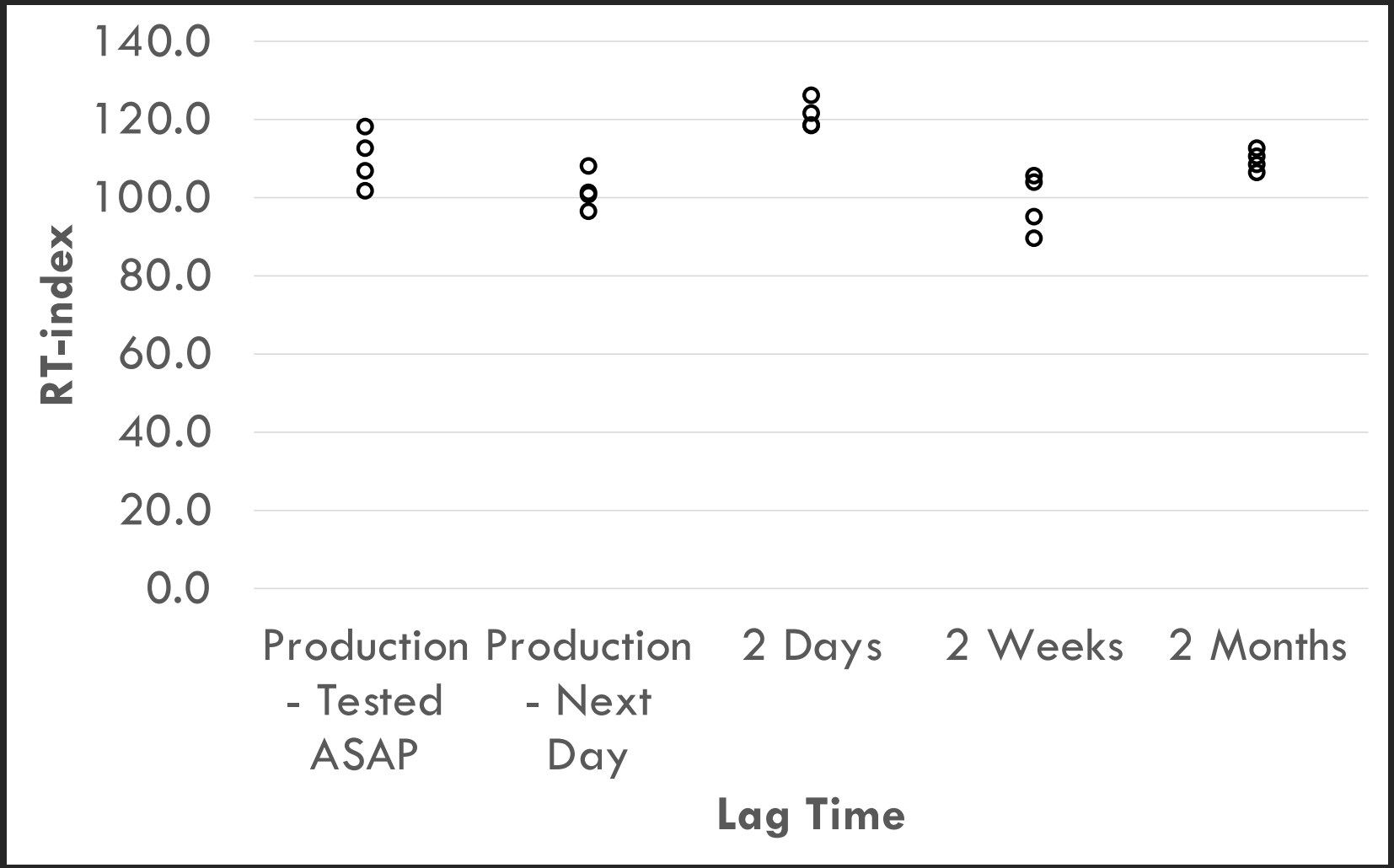
# $RT_{index}$ 1 Week Dwell

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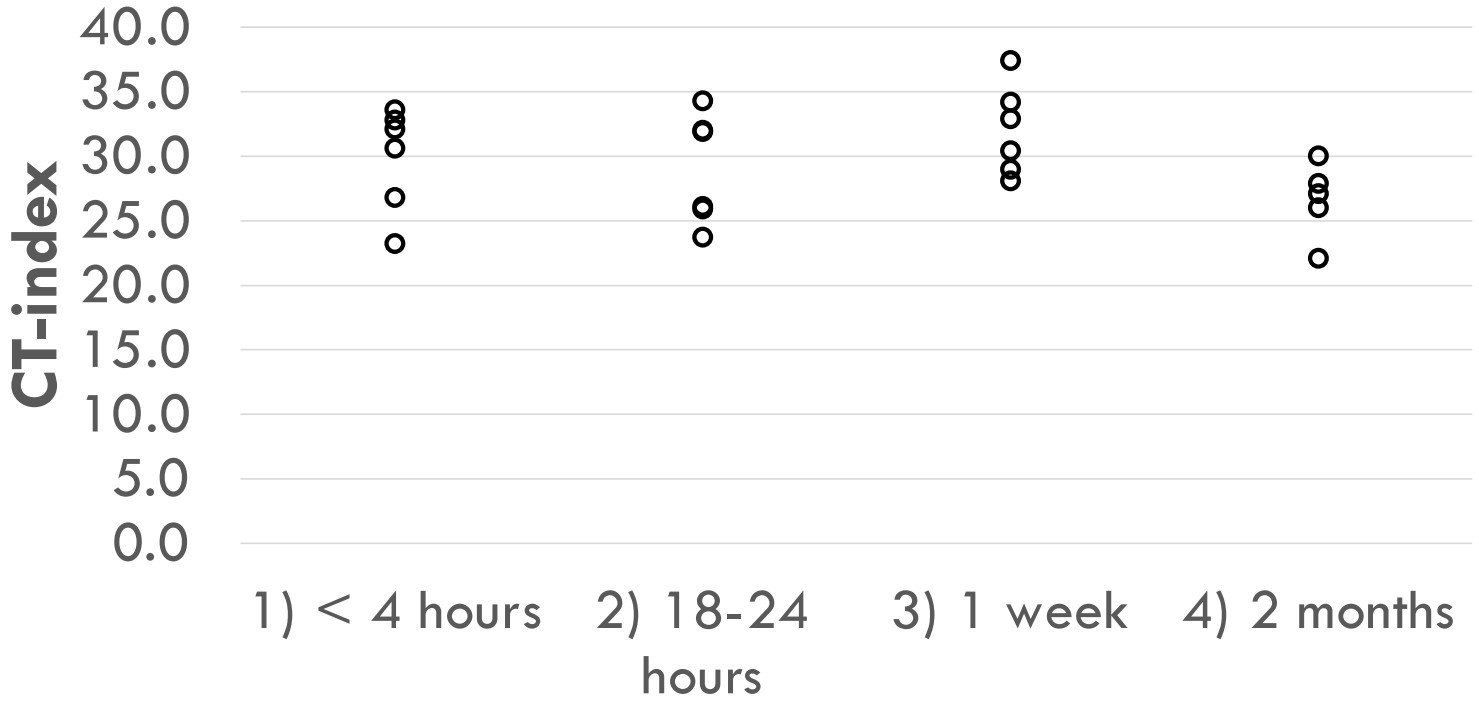
# Impact of Dwell Time

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# NCAT #1 Summary

- $CT_{index}$ from 24.7 to 32.0
  - No clear trend for dwell or lag time
  - Lower variability at 2 month lag time
- $RT_{index}$ from 98.5 to 121.2
  - No clear trend for dwell or lag time
  - Generally lower variability at longer lag time
- No practical differences with dwell differences

AL Mixture #1

# NCAT #2 Results

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# $CT_{index}$ Results

| Lag Time | No Dwell Time | | | 18-24 hours Dwell | | | One Week Dwell | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg. CT Index | SD | COV (%) | Avg. CT Index | SD | COV (%) | Avg. CT Index | SD | COV (%) |
| No Reheating | 61.8 | 9.0 | 14.5% | 64.4 | 5.1 | 7.9% | 67.5 | 12.2 | 18.1% |
| Two Days | N/A | | | 54.3 | 7.9 | 14.5% | 55.5 | 3.2 | 5.7% |
| Two Weeks | N/A | | | 45.8 | 5.6 | 12.3% | 56.4 | 4.6 | 8.2% |
| Two Months | N/A | | | TBD | | | TBD | | |

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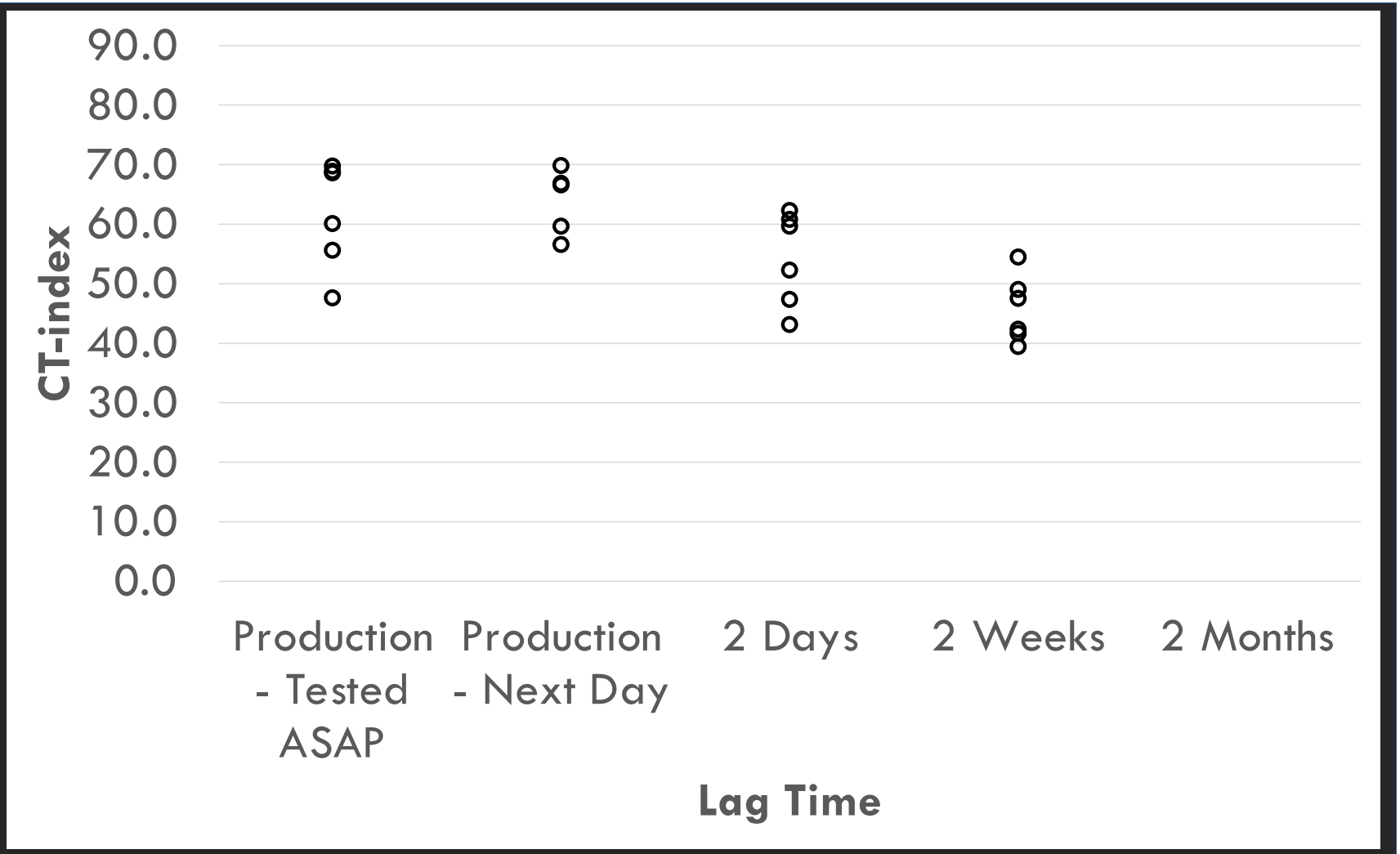
# $CT_{index}$ 18-24 Hours Dwell

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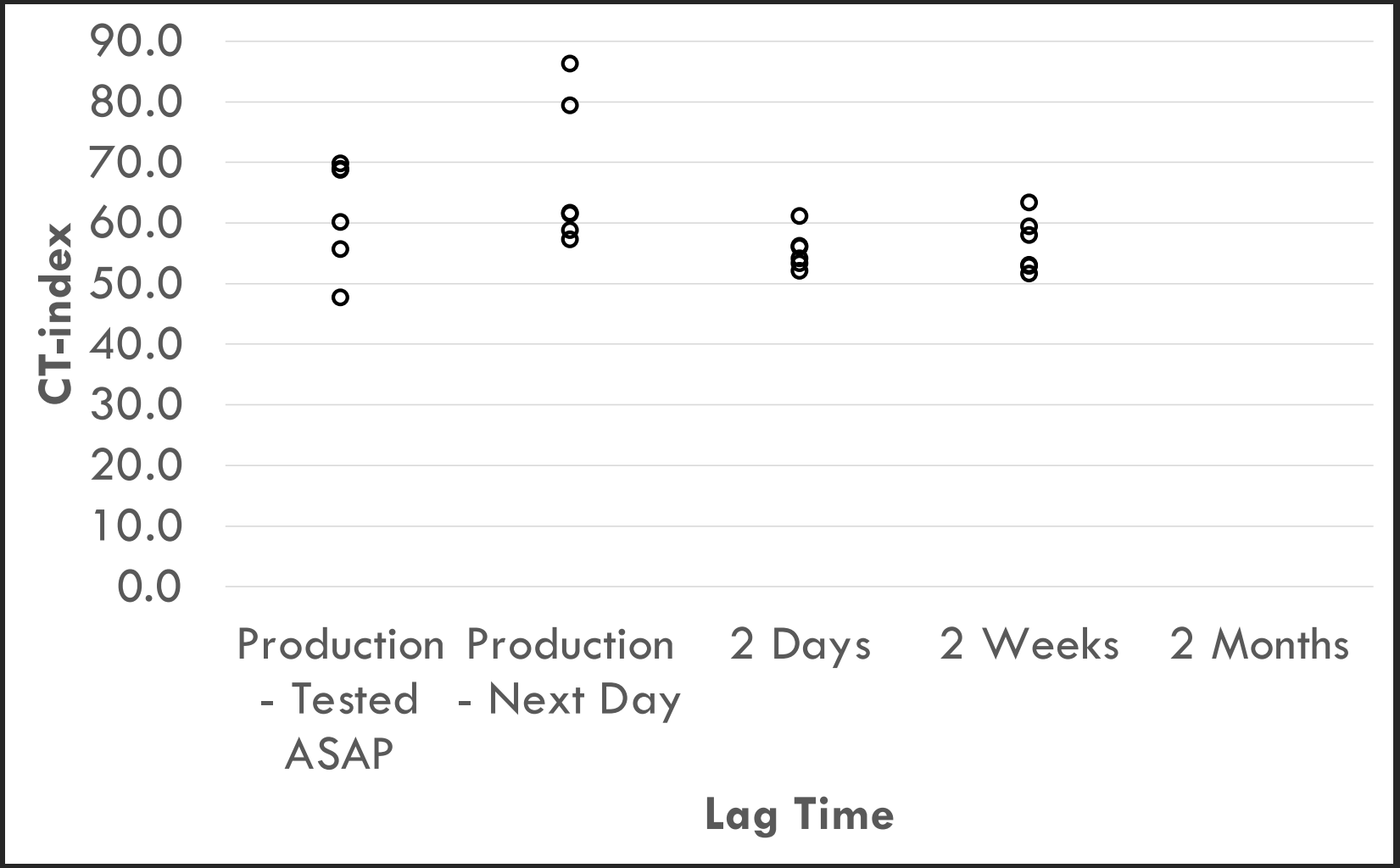
# $CT_{index}$ 1 Week Dwell

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# $RT_{index}$ Results

| Lag Time | No Dwell Time | | | 18-24 hours Dwell | | | One Week Dwell | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg. RT Index | SD | COV (%) | Avg. RT Index | SD | COV (%) | Avg. RT Index | SD | COV (%) |
| No Reheating | 87.0 | 3.7 | 4.2% | 86.4 | 3.0 | 3.5% | 82.6 | 1.2 | 1.5% |
| Two Days | N/A | | | 89.8 | 5.0 | 5.6% | 87.5 | 3.4 | 3.9% |
| Two Weeks | N/A | | | 92.7 | 4.2 | 4.5% | 89.9 | 4.7 | 5.3% |
| Two Months | N/A | | | TBD | | | TBD | | |

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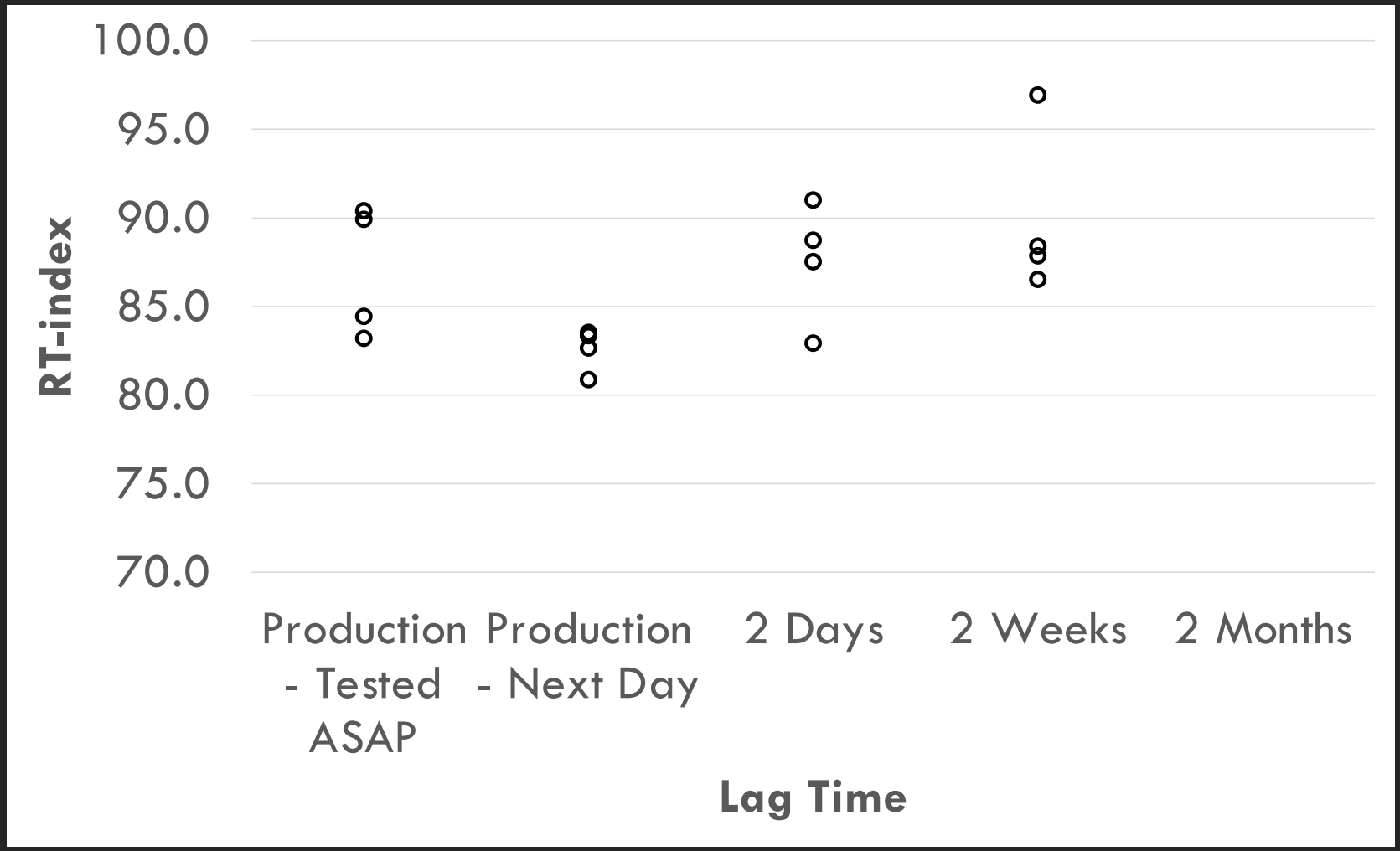
# $RT_{index}$ 18-24 Hours Dwell

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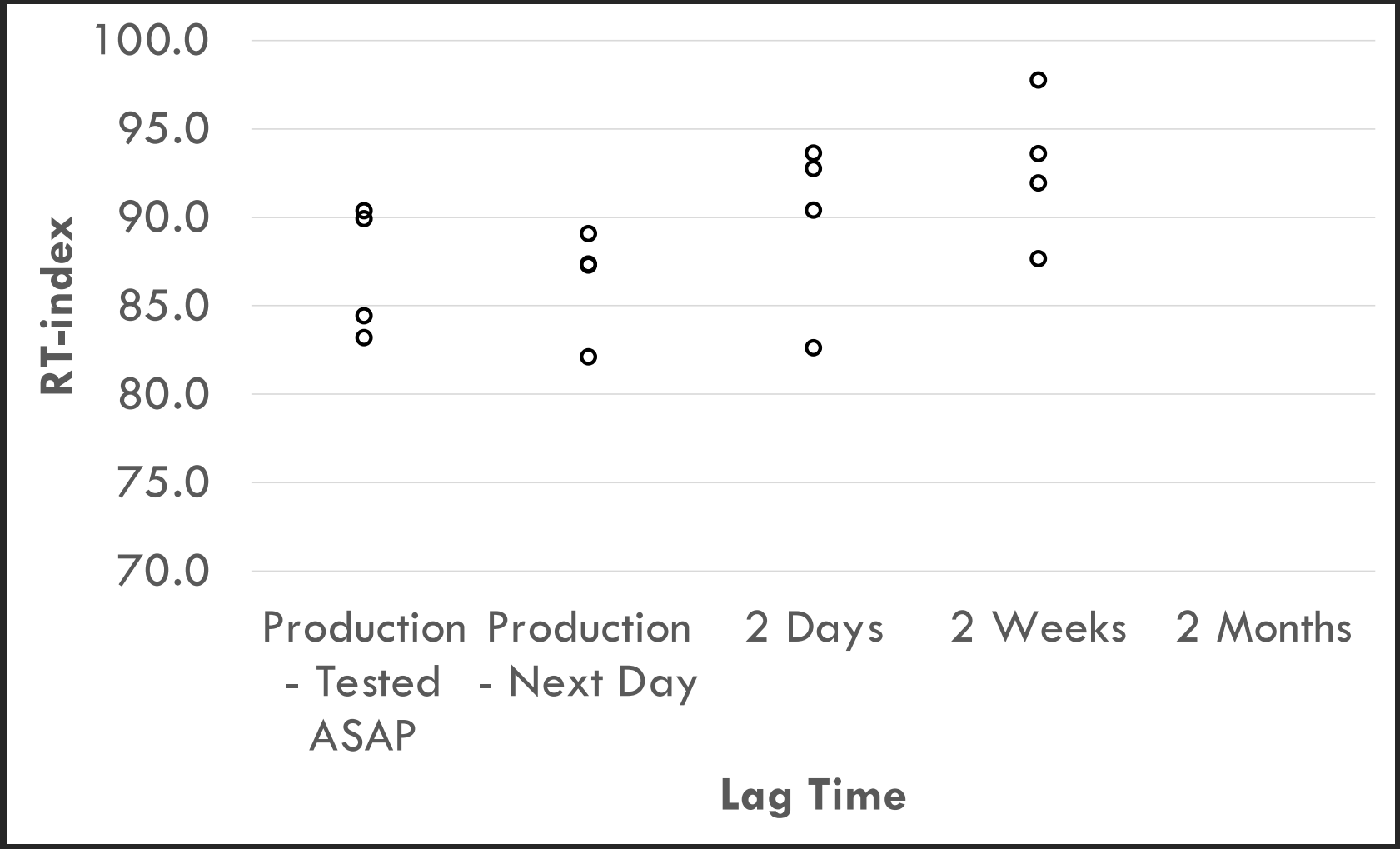
# $RT_{index}$ 1 Week Dwell

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# NCAT #2 Summary

- $CT_{index}$ from 45.8 to 67.5
  - No clear trend for dwell or lag time
- $RT_{index}$ from 82.6 to 92.7
  - No clear trend for dwell or lag time
- No clear trend on variability

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# Findings

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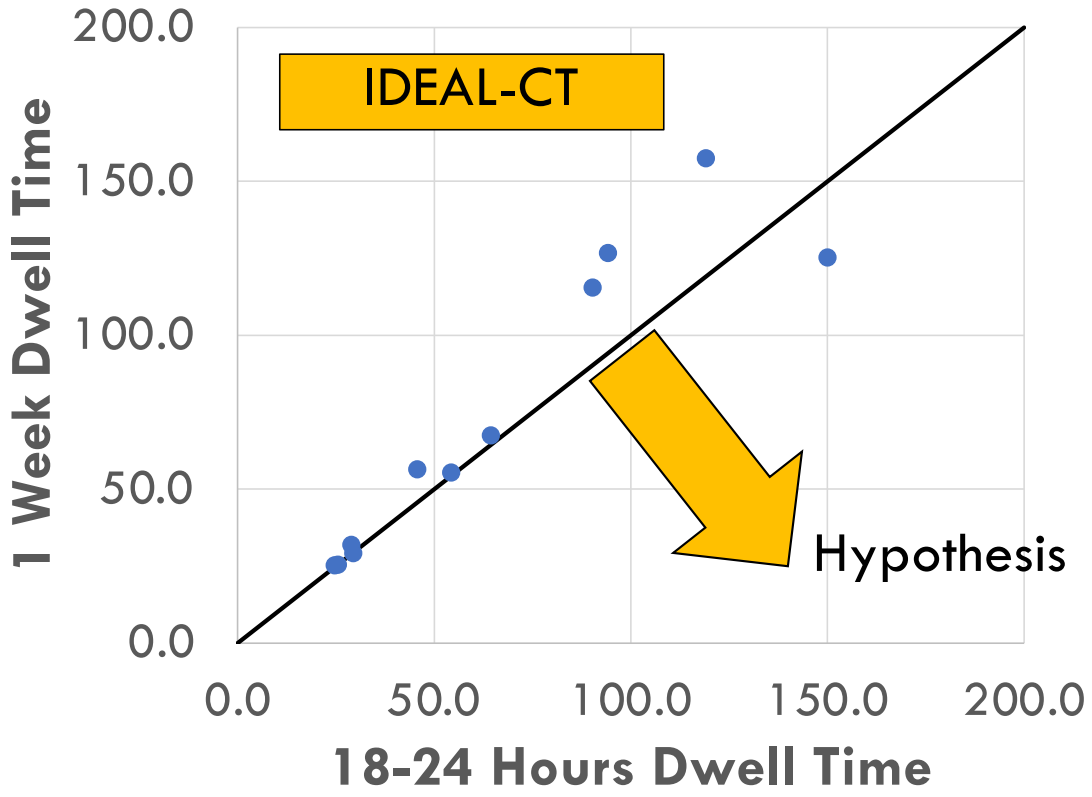
# Findings so far…. (subject to change)




- Dwell time does not appear to be significant in all three mixtures tested – even when brought out to a timeline of two months

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# Findings so far…. (subject to change)

- Lag time shows some differences but lost in the overall variability or noise of testing.
- Other states (VA) have reported significant differences with reheating

Looking to replicate this experiment in other regions / climates / mixes

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